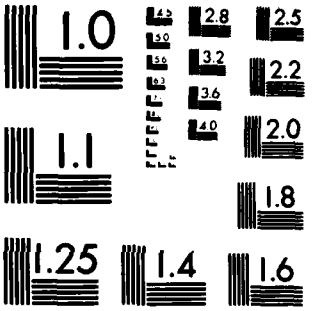
AD-A129 656 A SELECTION CRITERION FOR ASSESSING NEW PROPELLANT 1/1
BINDERS(U) NAVAL WEAPONS CENTER CHINA LAKE CA
A ADICOFF APR 83 NWC-TM-5005

UNCLASSIFIED F/G 21/9.2 NL

END
DATE FILMED
7 83
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

AD A129056

NWC Technical Memorandum 5005

A SELECTION CRITERION FOR ASSESSING NEW PROPELLANT BINDERS

by

Dr. Arnold Adicoff
Research Department
for the
Naval Sea Systems Command

April 1983

Approved for public release; distribution unlimited. This is an informal report of the Naval Weapons Center and is not part of the permanent records of the Department of Defense.

DTIC FILE COPY

DTIC ELECTE JUN 20 1983 A

NAVAL WEAPONS CENTER
China Lake, California 93555

83 06 20 092

FOREWORD

The work in this report was undertaken while the author was on tour at the Naval Sea Systems Command during the period from June 1981 to June 1982. The author's sponsor, Mr. John Murrin, SEA 62R2 suggested the topic in order to help screen new candidate materials for energetic binders. The concept was developed during the tour and a preliminary draft of this document was prepared. The work was completed in this final form upon the author's return to the Naval Weapons Center in September 1982.

This report is being issued in order that the methodology presented can be considered by the propulsion community in guiding binder development. The report has more general utility in that the method can be extended to the evaluation of any engineering material.

The report has been reviewed and approved for publication by the sponsor.

E. B. ROYCE
Research Department
February 1983

ACKNOWLEDGEMENT

The author appreciates the opportunity given him by Mr. Murrin to examine the propellant binder selection process. The author also desires to acknowledge the helpful and thought provoking discussions he has had with Dr. Carl Gotzmer of the Naval Surface Weapons Center, Indian Head.

NWC TM 5005, published by Code 38, 166 copies.

ABSTRACT

A selection criterion, S.C., for evaluating binders for propellants has been developed. This criterion uses an alogorithm which includes terms for changes in energy, hazards, mechanical properties, processing, cost, and technical risk. The uniqueness of the method is that it uses measured properties of the new material and compares those properties with those of an existing engineering material of a similar kind. The method may have broader utility than in binder selection because a complementary set of properties and procedures can be used to evaluate other new materials for replacement applications.

INTRODUCTION

There is a problem of value judgement that confronts the technologist and project engineer in the selection of material when newly invented materials are considered as a replacement for existing materials. If the proposed material is a "research" material and available in limited quantity the judgement involves the extent to which this new material provides advantages that would offset the cost of the new material. In the case of propellant binders, the Military Departments and their contractors are the only customers and must, in one way or another, provide the financial support to make the "research" binder into an engineering material. An engineering material is a material produced in large enough quantities and is adequately characterized to be used in a production process. In a sense, this is a manifestation of the classical research versus applications discussions. The researcher spends much time and effort to synthesize new energetic polymers that hold promise of increasing propellant energy and performance. The propulsion technologist must have hard answers to the questions; "What gain? What loss? and What cost?"

This paper attempts to assess the desireability of investing scarce resources in large scale binder development by providing a material selection criterion which incorporates, where possible, experimentally measureable values. Subjectivity does occur in the selection of properties and development the interaction equation. The results of the evaluation can be given as a single numerical term. It may be also instructive to tabulate the two major terms one consisting of impulse increase per cost increase and the second consisting of a composite term of experimental hazard, mechanical property, and processing factors.

An important feature of this approach is the comparison of the changes in properties imparted to a propellant when a known binder is replaced by a new binder of similar kind in the propellant. The property, P, being considered will be used in a non-dimensional (ND) form obtained by dividing the experimently determined property of the new (n) material by that of the reference (r) known material of similar kind as in Equation (1). The incremental (i) improvement will be evaluated according to Equation (2).

$$P_{ND} = \frac{P_n}{P_r} \tag{1}$$

$$P_i = \frac{P_n - P_r}{P_n} \tag{2}$$

The factors that are included in this criterion are mechanical properties, hazard potential, a processing characteristic, the propellant energy, cost, and technological scale-up risk.

MECHANICAL PROPERTIES

For the sake of simplicity, the two mechanical property terms selected for comparison are the propellant ambient temperature constant strain rate test maximum stress value (σ_{max}) and the rupture strain (ε_b). These values are used when σ_{max} and ε_b occur within a "reasonable" range. For the case of highly extensible propellant, the stress and strain values used for this evaluation should be the values at the point where the stress-strain curve becomes markedly non-linear. (The reference propellant in this latter case should also be highly extensible.) The property of engineering interest is the toughness of the propellant which will be designated τ and defined in Equation (3) as:

$$\tau_{ND} = (\sigma_{max})_{ND} \; (\varepsilon_b)_{ND} \tag{3}$$

If the properties at low or high temperature are important for an evaluation, then τ should be evaluated at the temperature of interest. It is noted here that toughness has never been defined in quantitative terms but, as used in this presentation, represents a measureable propellant quality.

HAZARD SENSITIVITY

Hazard sensitivity, S, is a composite of several hazard related terms. The selection of tests is arbitrary but includes the major hazard tests often used on propellant. The terms are arranged so that propellants that are more hazardous in each of the separate tests rapidly decrease the selectiveness of that material. In the case of vacuum thermal stability the test may be inappropriate when certain propellants, such as rubber based composites, are considered and should not be included. For energetic binders the following terms are included:

1. Impact test (NAVORDINST 8020.3) — h_{ND}
2. Vacuum stability (MILSTD 286). Volume of gas produced in 40 hours — V_{ND}
3. Friction sensitivity OD44811. Force required to initiate a reaction — f_{ND}
4. Critical diameter. The diameter of a propellant motor required to sustain a detonation according to OD44811. — CD_{ND}

The hazard sensitivity parameter is defined according to Equation (4)

$$S = \frac{V_{ND}}{h_{ND}\ f_{ND}\ CD_{ND}} \qquad (4)$$

PROCESSIBILITY

A measure of the processing characteristics is the propellant viscosity. In general, the lower the mix viscosity the easier the propellant mixing and casting. Within the approximate nature of this assessment, the value of the viscosity at the end of mix, η_{ND}, is considered as the measure of processibility.

ENERGY

A traditional measure of the energetic usefulness of a propellant is the specific impulse of the propellant. Since a purpose of any energetic binder program is to increase the energy content of the system, the specific impulse is compared at the same total solids content. In this criterion the incremental specific impulse $(I_{SP})_I$ is used. Since the interest is in higher energy systems, any materials that decrease the energy are not considered and have no value in this assessment.

COST/TECHNOLOGICAL STATUS/TECHNICAL RISK

The value factor is defined as the fractional improvement in performance per fractional increase in cost of the new system. This form is introduced to provide the selection criterion with consistency so the larger values of the selection criterion are more desirable than low values. It should be noted that the reciprocal of this term when multiplied by the cost of the reference propellant and divided by the specific impulse of the reference propellant does provide the increased cost per increase in unit performance.

The actual cost of any propellant is the sum of the costs of the materials to which is added the handling, processing, and storage costs. If to a first approximation one assumes that for a new propellant material all costs in preparing the propellant are approximately the same as for an existing comparable propellant, then it is possible to assess the increased cost of the new propellant when the new binder system is introduced. A technology risk factor R is introduced because the new material has not been produced in quantity. Experience has shown the first cut cost estimates of production of a material from laboratory and pilot plant processes are optimistic. The risk of arriving at the predicted cost is evaluated according to the complexity of the process, i.e., the number of processing steps required to convert a raw material into the finished commercial material. If the process requires one or two chemical reaction steps, a 90% confidence level in predicting the cost is assigned, for a three to five step process a 50% confidence level is assigned, and for steps in excess of five the confidence level is lowered to 25%.

$$C_P = C_B + C_x$$

$$C_{Pr} = C_{Br} + C_{xr}$$

$$C_{Pn} = 1/R\ C_{Bn} + C_{xn}$$

where C is cost

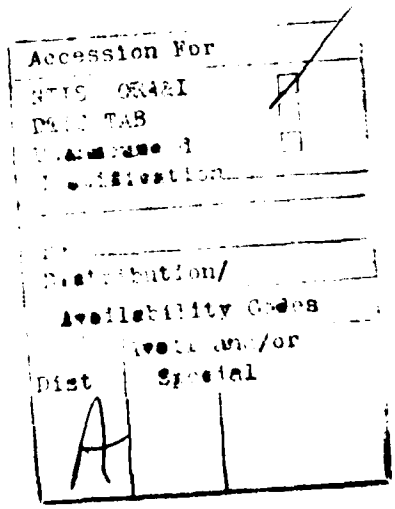
subscript P refers to propellant
B refers to binder
x all other non-binder propellant costs

The incremental cost of a new propellant is given in Equation (5)

$$(C_p)_i = \frac{\frac{1}{R}C_{Bn} - C_{Br}}{C_{Pr}} \qquad (5)$$

The selection criterion, S.C., is now obtained with Equation (3), (4), and (6) in which the two terms can be multiplied to obtain a single numerical value. It will be useful to also present the values of the two terms separately for analysis of the results.

$$S.C. = \left[\frac{(I_{SP})_i}{(C_P)_i}\right]\left[\frac{\tau_{ND}}{n_{ND}\, S}\right] \qquad (6)$$

SUMMARY

A procedure for developing a material selection criterion has been suggested for the selection of new binders for propellants. The procedure involves the use of properties of the new materials compared to those of a similar known material. In the case of propellants these properties include those related to mechanical behavior, processing and safety. The method also includes the improvement of energy content as a function of increased cost. Within the cost factor, the technical risk in scaling a new material to a commercial scale production process is included.